4-29-2016

Blue Eyes on Red Lists: Conservation and the Future of the Blue-eyed Black Lemur

Katherine Meier
Macalester College

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Katherine Meier

Macalester College – Department of Anthropology

Senior Capstone

4/29/16

Abstract:

The family *Lemuridae* represents a large and important group within the order Primate. Today, lemurs—endemic to Madagascar—are the most threatened mammal group on Earth. Almost every one of the 100-plus recognized species suffers from habitat destruction and other anthropogenic pressures. The IUCN lists the blue-eyed black lemur (*Eulemur flavifrons*) as critically endangered. Models suggest it will go extinct within the next decade and so far, conservation efforts have so far yielded little measurable success. For the blue-eyed black lemur, captive populations—typically serving as buffers against extinction— are experiencing problems that keep them from being viable for reintroduction into the wild. The reasons for these problems are unknown. Unlike in the wild, however, captivity is a human-controlled environment. Managers have the power to control for environmental variables. Additionally, reproductive technologies exist that would allow for an immediate solution to the low reproductive success of these lemurs. Given the time-frame predicted for this species, it is imperative that we, humans, act now and do all that is within our power to sustain the blue-eyed black lemur for generations to come.

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INTRODUCTION

This paper addresses the future of a species that shares our taxonomic order: Primate. Lemurs are found only on the island of Madagascar and represent more than 20 percent of primate species in the world. Shockingly, nearly all species are listed by the International Union for Conservation of Nature (IUCN) as endangered (if not 'critically endangered') making lemurs the most threatened group of large vertebrates in the world (Schwitzer et al. 2014). How does this relate to us? Primatology is an integral component of the study of human evolution. Lemurs - *Kingdom:Animalia, Phylum: Chordata, Class: Mammalia, Order: Primates, Suborder: Strepsirrhini, Family: Lemuridae*—split from a shared, ancestral primate as early as 65 million years ago (Yoder and Yang, 2004). Historically, when discussing the evolutionary path that has led to us, lemurs have been used as analogs for primitive primates. While the ancestor we both share is indeed very primitive, lemurs have been evolving on the isolated island of Madagascar since that time. Today, not only do they hold evolutionary significance for us, but we recognize them as keystone species in some of the most endemic and threatened ecosystems in the world.

With population numbers and habitat area continually dwindling, the methodology and effectiveness of both in-situ and external conservation efforts are debatable. Using the blue-eyed black lemur (*Eulemur flavifrons*) as a case study for the plight of lemurs as a whole, I argue that the environmental conservation measures in place in Madagascar are not enough to save this species; the pressures driving it towards extinction in the wild—most of which are anthropogenic—can at best be slowed, not stopped. In light of this, I believe that more emphasis needs to be placed on ex-situ conservation methods—namely, captive breeding. The captive breeding of 'reserve populations' is considered by most conservationists to be a last-resort option for species preservation. My argument does not aim to diminish the importance of attempting to preserve and maintain wild habitats and their biodiversity. However, given the current status of this lemur and its habitat in the wild, paired with its relatively unsuccessful history of breeding in captivity, a more aggressive approach to captive breeding must be taken if this species is to continue to exist.

In this paper I will aim to address the threats posed to the blue-eyed black lemur in the wild and outline what conservation measures have been enacted to counter those threats, concluding that they have, thus far,

not been successful. I will then discuss the role of captive populations, breeding and zoos as conservation tools for critically endangered species like the blue-eyed black lemur, and describe the status of this species in captivity today. Finally—based on published research as well as personal observation and study of the ecology/behavior of this lemur—I argue that there are specific actions we can take to improve its captive populations and make significant progress in its conservation. Despite their uniqueness and importance, lemurs, as a whole, are comparably marginalized taxa within the large world of ex-situ conservation. An adaptable, representative and iconic species like the blue-eyed black lemur needs a stronger, more viable 'reserve population,' promoting awareness and support, and assuring its survival into the future.

LEMURS: PAST AND PRESENT

The Most 'Primitive' Primates

Anthropologists, biologists, and psychologists, to name a few, are all stakeholders in the study of primatology—the study of non-human primates. In studying a primate's environment, morphology or behavior, researchers search for correlates in our own human equivalents. Do the wrist bones of a brachiator such as the gibbon show as much flexibility as our carpals? Do female spider monkeys invest as much energy towards rearing their offspring as we do? When two bonobos groom each other, do they feel comradery, strengthening social cohesion? We search for these correlates with the understanding that we, humans, are special. To find a parallel in another animal would give us insight into the evolution and workings of that specific trait and how we have arrived at where we are today. And it is through this lens of evolution that primatology is set apart from the study of any other group in the animal kingdom. Non-human primates are our closest living relatives and we are self-interested. The evolution of our species is a story of splits and delineations. The further back in the fossil record one goes, the less defined these separations become. Today, scientific evidence tells us that the first primate evolved from a rodent-like mammal around 55 million years ago (Klein 2009). From it branched all lineages leading to the extant primates we see today.

In light of our anthropocentric biases, it is to be expected that primate research often concentrates on the taxa which most recently split from our own lineage, because it is assumed that these groups will have more in common with us. Indeed, in his chapter on primate evolution, Richard Klein (2009) "begins with those taxa that are most closely related to people and proceeds downward through to progressively more distant relatives which are treated in progressively less detail" (75). Chimpanzees are the apes who share the most recent common ancestor with humans; the split is estimated as having occurred around 6-7 million years ago. However, in geologic time, given that the earth is about 4.5 billion years old, chimps and humans have existed (as we know them today) for a very short time. Hence, primatologists and humans in general have shown an increasing fascination in our older relatives.

The very first evolutionary split from the last common ancestor of primates divided the order into two suborders: Strepsirhini (known as 'lower primates' or prosimians), and Haplorhini (Anthropoids and Tarsiers). Today's extant haplorhines include New World monkeys, Old world monkeys, Apes and Humans. The strepsirhines are represented mostly by lemurs. Klein (2009) asserts that the strepsirhine clade constitutes "the best available living model for the last shared ancestor of the Primates" (90). This idea—that lemurs (which make up the majority of the prosimians) are primitive primate analogues—is commonly misunderstood by the general public. Take, as an example, the title of an article on lemur research in the popular media source *Science Daily*; "*Hanging Around with Lemurs, The Planet's Most Primitive Primate"*. While lemurs are the group of extant primates most distant from us, people often misinterpret the idea of 'primitive' to be analogous with 'unevolved.' For those without a comprehensive grasp on primate phylogeny, lemurs hold a sort of alien fascination; To many, humans are the 'most' evolved primates while lemurs are the least so. While the title of that article is indicative of this common misconception, one only has to read a page and a half into the report to be reminded of the fact that "time hasn't stood still for them (lemurs). They've also evolved during the 65 million years since primates first began evolving" (University of Southern California 2007). Lemurs are not 'unevolved.' While they may be useful for those interested in reconstructing a likeness of the first primate ever, it is ultimately their very distinct evolutionary history that makes them worth studying.

Lemur Evolution - In a League of Their Own

An evolutionary split—a speciation event—occurs when some members of a population experience genetic isolation from the others. This can happen through a number of mechanisms and there is debate over how to define a species. The most common definition is the biological species concept (where a species as a population of individuals which can breed to produce viable offspring) and the most common mechanism for speciation is some kind of geographic isolation[1]. Lemurs are only found on the island of Madagascar. Madagascar itself—located today at 430 km east of Mozambique—separated from the African mainland at an estimated 170 million years ago. The first lemur ancestors are subsequently thought to have arrived on the island around 80-60 million years ago on a raft of debris and vegetation (Klein 2009). More recent genetic analysis has supported and narrowed the age estimate of the lemuriform clade as being approximately 62–65 million years ago (Yoder and Yang 2004). The arrival of the first prosimians on Madagascar initiated their isolated evolution; independent of competition from monkeys, apes or any other large-bodied mammals, they were able to radiate into the numerous environmental niches found nowhere else in the world.

Today, there are considered to be five families within the superfamily *Lemuroidea.* All five are endemic to Madagascar and the nearby Comoro Islands. Together, they represent more than 20 percent of the world's primate species and are remarkably diverse (Schwitzer et al. 2014). Unlike most other primates which range across the Neotropics, Africa and Asia, lemurs have a small geographic range, confined to their island home (a fact which makes their species-level diversity even more impressive). Human primates stand in extreme juxtaposition; we can be found in every part of the world, a limitless geographic range. It was when humans arrived on Madagascar that lemurs encountered major competition. Since that time, humans have played a heavy-handed role in the ecological evolution of the island.

Natural selection, the mechanism of evolution outlined by Charles Darwin in *On the Origin of Species* (1859), rules a world where species are constantly changing according to the pressures of their natural environment. Life, therefore, is a constant struggle to survive. Those who happen to be the best suited to the

[1] For a more in-depth discussion of the theories and mechanisms species classification, see Klein (2009), p. 3.

prevailing environment will be the most successful, outcompeting others for limited resources. It is a natural process. However, in the last couple hundred years especially, this process has spelled out disaster for many non-human species and their environments. A debate rages over the role of human pressures as a part of or separate from the rest of nature. Especially with technological advances and in the face of the pressures of globalization and development that we see today, many wonder if we have set ourselves even further apart from the rest of the natural world (expounding upon humans' previously mentioned anthropocentric tendencies). We live in a new geologic time period: the Anthropocene, designated by the observation that there is nowhere left on Earth unaffected by human activities (Dirzo et al. 2014). Madagascar is no exception. The complex history of the Malagasy people and their natural environment is a narrative often dominated by exploitation and destruction. As a result of this relationship as well as many external pressures, lemurs—one of the largest, most diverse, most geographically isolated groups of primates in the world—have earned another superlative: The most threatened mammal group on Earth (Schwitzer et al. 2014).

THE BLUE-EYED BLACK LEMUR (*Eulemur flavifrons*)

Status in Madagascar

Every two years, a conglomerate of primate-specialist organizations draws up a list of '*The World's 25 Most Endangered Primates*.' The blue-eyed black lemur (*Eulemur flavifrons*) —one of the 101 lemur species currently recognized[2]—has held a place on that list since its elevation to full-species status in 2008 (Andriaholinirina et al. 2014).

Also known as Sclater's lemur, this species is of medium size (1.87–2.04 kg) with males being completely black and females being a reddish-brown color. Arboreal, frugivorous and cathemeral, it exhibits the unusual characteristic of female social dominance that is seen in multiple lemur species; These social groups range in size from 4 to 11 individuals (Volampeno et al. 2010). Indicative in its name, the blue-eyed black lemur is the only primate other than humans to consistently have blue eyes (Mittermeier and Nash

[2] This number is highly mercurial in part due to indefinite methods and qualifications for speciation.

2008). ‘Undiscovered’ until as late as 1984 and then suffering a subsequent dearth in research/interest, it has been this winsome phenotype along with the species’ taxonomic separation from *Eulemur macaco* (the black lemur) that has been primarily responsible for its now iconic status as the flagship species for conservation within its habitat: The Sahamalaza Peninsula.

The blue-eyed black lemur has one of the smallest distributions of any lemur species. It is found only in a concentrated area of Northwestern Madagascar, the Sahamalaza Peninsula. This area was declared a The United Nations Educational, Scientific and Cultural Organization (UNESCO) Biosphere Reserve in 2001 and established as a national park by the Malagasy government in 2007 as part of a country-wide effort to increase protected areas. The Sahamalaza-Iles Radama National Park (fig. 1) is home to a number of rare and endemic ecosystems both marine and terrestrial: mangroves, coral reefs and sub-humid transitional forest fragments (AEECL 2015). Besides *E. flavifrons*, there are at least two other species of lemur endemic to the park: the sahamalaza sportive lemur and the northern giant mouse lemur. Sahamalaza earned its national park designation nine years ago as a treasure-trove of biodiversity. Awareness of and interest in the area has

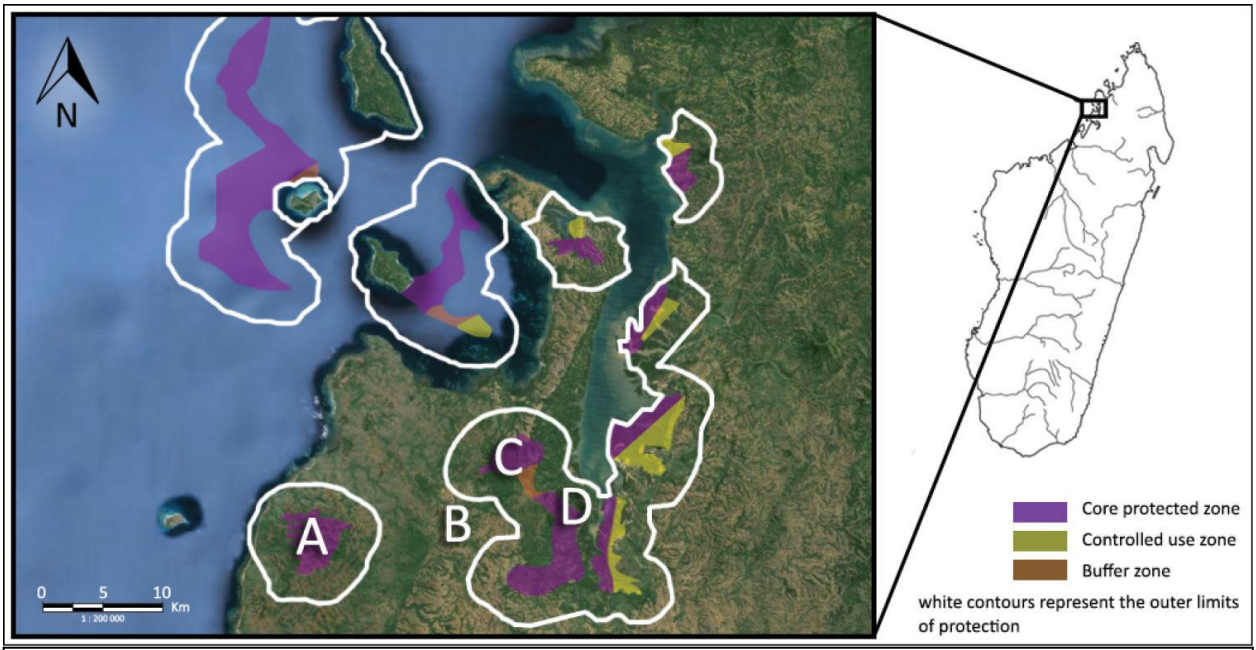

Fig 1: The Sahamalaza Peninsula:
Located in northwest Madagascar, indicating sites of (A) Ankarafa Forest, (B) Antafiabe Village, (C) Anabohazo Forest and (D) Betsimpoaka village (Penny et al. 2014).

grown proportionally since that time, with the blue-eyed black lemur serving as the poster species for its conservation.

The Plight of Sahamalaza and Its Lemurs

At the time of its assignation as a UNESCO biosphere reserve in 2001, the Sahamalaza-Iles Radama peninsula was given 153,302 hectares of total protected area (core protected areas, buffer zones and transition areas) (UNESCO 2001). Only four years later, in 2005, prior to its official decree as a national park in 2007, the Malagasy government issued an immediate temporary protection of core zones of the future protected area for the park: a total of about 26,000 hectares (AEECL 2015). This rapid 127,302 hectare decrease of original natural habitat is only a momentary snapshot of what has plagued, and continues to plague, the peninsula. It also epitomizes the trend in Malagasy environmental protection throughout history. For comparison, evidence suggests that over the 20 year period from 1990 and 2010, total intact forest habitat in Madagascar went from covering an area of 106,600 km^2 to an estimated 92,200 km^2, a 14,400 km^2 reduction. One popular statistic[3] often referenced when discussing Madagascar's environmental history is that only 10 percent of the original forest cover is left on the island today (Schwitzer et al. 2014).

The biggest threat to the blue-eyed black lemur comes from habitat loss from slash-and-burn agriculture (*tavy*) which both serves as the main method of cultivation and has deep-rooted cultural significance in Madagascar. This can have unintendedly large impacts as fires are hard to control and spread easily. The two forest fragments in Sahamalaza, Anabohazo and Ankarafa, were, until recently, joined by a third, Analavory. This third forest was completely destroyed by a man-made fire in 2004 (Volampeno 2009). Locals also practice selective logging of trees for export (valuable woods such as rosewood and ebony) or firewood. Direct human exploitation of lemur populations in Sahamalaza is also a problem. The lemurs are one of the only native large-bodied mammals in Madagascar and have historically served as an important food/protein source for many local human populations. One study suggested that, without bushmeat such as lemurs as an

[3] This claim assumes full forest cover of Madagascar before human arrival. see McConnell and Kull (2014).

available food source, rates of anemia in country would increase by 30%, leading to increased mortality, morbidity and learning difficulties. However, it asserted that the current levels of bushmeat extraction are "clearly untenable" (Dirzo et al. 2014); a 2004 study in Sahamalaza found a lemur trap density of up to 570 traps/km2 (Andriaholinirina et al.2014). Lemurs are also often captured for pets. Illegal but widespread, this practice is being re-examined as having a larger impact on lemur populations that previously thought. More recently, documentation and awareness that hotels in Madagascar are keeping lemurs as pets has increased. As national icons, they're meant to draw tourists and boost business (Watson 2016). There is no official record or documentation of how many lemurs exist in illegal captivity in Madagascar; however, the issue is currently being more intensely examined[4].

A more recently acknowledged concern for the survival of this species evolved with the realization that the existing populations were interbreeding with groups of black lemurs (*Eulemur macaco*) around the southern borders of their geographic range, close to the Manongarivo Reserve (Andriaholinirina et al. 2014). This hybridization, likely a result of displacement from extreme habitat loss, holds negative implications for the blue-eyed black lemur given the biological species concept. Should what few *E. flavifrons* that remain breed with this separate but closely related species, there is the potential for permanent loss of species-specific behaviors and even the extinction of either or both species (Eschmann 2015). Due to habitat loss and direct human exploitation, the blue-eyed black lemur has experienced an 80% population reduction over the last 25 years (AEECL 2015).

CONSERVATION

Conservation in Sahamalaza

[4] Schaefer and Reuter (2016) have developed a public online survey where anyone can report seeing a pet lemur (http://www.petlemur.com). They hope this accessible technology will facilitate a more comprehensive picture of lemurs in illegal captivity in Madagascar.

The creation of protected areas has been a primary mechanism of conservation for a long time. National parks and reserves can be found worldwide, housing what people deem to be the most important or imperiled cultural and natural resources in the world. These measures create areas of limited human use or contact.

The Sahamalaza-Iles Radama national park is divided into zones (Fig 1): core protected zones, areas with the highest level of protection and least use by people other than for non-destructive research; buffer zones, typically around core areas and used for environmental activities and practices such as education and ecotourism; and controlled use zones, sometimes containing human settlements, areas for the habitat stakeholders to collaborate for better conservation. The forest fragments, last homes of the blue-eyed black lemur, are core protected zones, theoretically relieving them from human exploitation.

Sahamalaza is one of many national parks in Madagascar, all of which are run by Madagascar National Parks. MNP says that its mission is to, "establish, maintain and sustainably manage the national network of Parks and Reserves, representative of the biodiversity and natural heritage unique to Madagascar" (Madagascar National Parks 2015). Their statement is clearly motivated by the intrinsic value of Madagascar's biodiversity - objective and quantifiable.

Conservation, however, is generally recognized to be a very subjective and complex effort due to the number of human actors invested in a given effort, many with less intrinsic motivations. At the simplest level, conservation in Sahamalaza has been invested in by the local people of that area, the Malagasy government and many independent organizations outside of the country such as the World Bank or the AEECL. This complex nature of conservation is better illustrated by organizations like UNESCO, which have partnered with MNP in the creation of three out of forty-five of Madagascar's national parks (Madagascar National Parks 2015). UNESCO first designated the Sahamalaza peninsula as a biosphere reserve under its '*Man and the Biosphere'* (MAB) program which aims to "establish a scientific basis for the improvement of relationships between people and their environments" (UNESCO 2016). Intrinsic biodiversity value aside, this conservation measure clearly emphasizes the human element in both the past habitat degradation and future preservation of the area. The other conservation initiatives that have been

established to protect what's left of the blue-eyed black lemur habitat are a melding of ecological, social and cultural changes.

There are multiple conservation organizations working specifically on Sahamalaza. The largest, most active of these is the *Association Européenne pour l'Étude et la Conservation des Lémuriens,* or AEECL. Its focus on Sahamalaza and the blue-eyed black lemur began in 2000 with a community-based natural resource management program. Since that time, the organization has implemented several community-level education and research initiatives within and surrounding the park. Examples include the formation of Local Community Associations, which give local community groups government-approved authority to undertake the management of their own areas, and Village Forest Protection Committees in all major villages, (fokontanys) which help monitor illegal activities in the park. The AEECL also offers locals a number of amenities: assistance with bureaucratic procedures, courses in sustainable agriculture, development of economy and tourism through handicraft, and organization of festivals to promote environmental awareness. And the AEECL is the organization responsible for the installation of the two research stations in Ankarafa and Anabohazo forests, the aim of which is to facilitate research of both Malagasy and foreign researchers, as well as establish researcher presence, in the core forest areas in order to deter illegal activities. Other groups working inside Sahamalaza include a Malagasy NGO, Mikajy Natiora, whose approach and focus is similar to that of the AEECL, combining ecological research with community education and outreach (Volampeno 2014).

Is it Working?

A lot of money and effort has been put into conservation efforts in Sahamalaza, yet habitat loss and decreasing blue-eyed black lemur populations, persist. All of the aforementioned problems and threats, whether specific to the peninsula or country-wide, continue inside and outside of nature reserve boundaries. All were magnified by the political crisis of 2009, when the government—which had prioritized conservation and tripled the country's total protected area—was overthrown in an unconstitutional coup. Since that time, the Malagasy government has been in a state of flux characterized by inefficiency,

corruption and instability. Lacking both funds from outside donor organizations (which had provided half of the government's annual budget) and law enforcement from relevant authorities, exploitation of protected areas has been on the rise since 2009 political crisis (Schwitzer et al. 2014).

Complications arising from cultural traditions and beliefs also exacerbate impediments to conservation. As mentioned above, the practice of 'Tavy' is deeply important in Malagasy society and local land ownership (Fritz-Vietta, Röttger and Kleemann 2009). Additionally in Sahamalaza, the rampant increase in wild pig populations clearly illustrates this problem. An introduced species, this pig digs up large areas of land, altering and disrupting the natural forestation processes. It is, however, considered 'fady' or taboo to kill these animals, allowing them to reproduce rapidly (Seiler, Randriatahina and Schwitzer 2010).

Poverty, political unrest and disorganization, and cultural traditions negate the efforts towards environmental conservation in Madagascar. In 2013 a site-specific, three-year action plan was published and indicated necessary steps for 30 sites containing endangered lemurs, Sahamalaza among them (Schwitzer et al. 2013). An important 2014 publication by the leading figures in lemur research succinctly summarized the main pillars of that plan within the context of the aforementioned impediments. These included promoting and expanding ecotourism, creating protected areas managed at the community level, and sustaining or expanding on long-term research presence in critical lemur sites (Schwitzer et al. 2014). My own study of *E. flavifrons* was conducted in the Anabohazo forest fragment of Sahamalaza in 2015. The research site I was working at was still in the process of being constructed, a twin to the one created by the AEECL in Ankarafa in 2004. While some documentation has indicated that these stations and researchers (established with the aforementioned goal of dissuading local exploitation of forest resources) have had measurable effect, many other sources say they are negligible. During my own study, as I traversed deep into Anabohazo to find *E. flavifrons*, I found evidence of human presence at every turn: From camp, I walked into the forest on a footpath known to the local guide. After a time, our route diverged from the footpath and descended a steep incline into a denser part of the forest. Along the path, defined by human footprints and those of cattle (zebu), there was obvious habitat destruction and the flora was secondary and comprised of brushy, small undergrowth. Even off the path, in the deepest parts of Anabohazo, there was evidence of zebu presence

(hoof-prints and excrement). There was a large area of burned forest at the center of one lemur group's apparent home range. The local people working at the research station included a cook, local guides and brick-builders. I often saw them emerge from the forest with newly-felled logs for firewood and other natural resources. For example, one day a huge bucket of honey comb was extracted from a hive within the forest (Pers. obs. 2015).

A 2012 publication by Seiler, Randriatahina and Schwitzer, articulates the hopelessness of the Sahamalaza situation at every level. Observing many instances of illegal activities and blatant disregard for park regulations, these members of the AEECL requested law enforcement assistance from MNP only to learn that "MNP did not have the money to send the police to take action against the poachers." Furthermore, they discovered a pervasive local perception of the AEECL as "bad people" who were restricting them from using the forests. In a situation such as this, a Malagasy-run NGO like Mikajy Natiora might be more successful in winning over and effecting change in local populations, but the authors assert that the task is beyond the means of small NGOs. Their article concludes by saying that, "in a political crisis situation like Madagascar's, it almost seems meaningless to call an area a national park, and people with criminal intent (or who simply need to feed their families) can be sure that nothing will happen if they hunt lemurs, so there is no reason for them not to do so" (Seiler, Randriatahina and Schwitzer 2012, 30).

The drivers of habitat destruction and environmental degradation in Madagascar are very clear and definitive, easily pinned to the practices of local populations who rank among the poorest in the world (Schwitzer et al. 2014). As such, it's clear why many conservation organizations like the AEECL have shifted a large portion of their attention towards rural education and development. They've struggled to 'empower' local people to be participants in environmental protection. But some see this bottom-up approach to conservation as a facade. A pivotal ethnography by Janice Harper (2002) was entitled "*Endangered Species: Health, Illness and Death among Madagascar's People of the Forest*." Focusing on a rural village in Ranomafana national park[5], the endangered species she references in her title are not any of the rare lemur species for which the area was reserved; she's talking about the people. Her study site was

[5] Located in southeastern Madagascar and established as a national park in 1991.

swept up into the geographic center of the park's conservation, administered by outside organizations including the World Bank, USAID, Duke University, and the Malagasy government. Villagers who had been living in that area for over a hundred years were forced to relinquish their rights to sacred, ancestral land and resources for only the promise of economic development and support which, for the most part, went unfulfilled. Her story asserts that "there are no people in the model of biodiversity" (Harper 2002, 40). The villagers of Sahamalaza, who view the AEECL researchers as 'bad people,' are part of a circuitous and reciprocal narrative of at-odds interests, illuminated by Harper's study. It is easy to vilify local populations whose practices clearly result in the destruction of natural habitats, placing conservationists on a pedestal where they can do no wrong. Often overlooked or ignored is the objectification and categorization of locals by conservation groups, who simplify ancient cultural and social relationships between people and their land and prioritize environmental preservation above all else. During my own short period in Sahamalaza, it was clear to me the influence that relevant conservation organizations exerted on power and social structures among local people. Those individuals who I interacted with and who were employees of the park or associated programs from the AEECL, exhibited a manner of superiority over others who I knew to be local farmers or merchants, unassociated with the park and just passing through or living close to our camp. The local guides and cook, hired from the nearest village, were accustomed to the high pay from western researchers, a strong and reliable food supply and many other forms of support which came with their job at the AEECL research station. A 2013 activities report by Guy Randriatahina notes that, during village conservation meetings around Sahmalaza, the AEECL representative made clear to local people that "only villagers participating in environmental activities are supported and will benefit from microprojects" run by the AEECL (Randriatahina 2013, 2). Meant to "motivate villagers," these statements simply further the evidence that many conservationists resort to coercive and manipulative measures which preferentially disturb traditional cultures and social frameworks.

The imposition of environmental conservation on local people parallels the history of human impact on the environment: new laws and impacts imposed upon systems that had been evolving and functioning long before their arrival in order to achieve subjective, population-specific goals. Humans have long acted in their

own interest and for their own advancement to, the detriment of the rest of the biotic world. Harper's study shows how, within the conservation narrative, the interests of a subset of the human population (the developed, western world) are enforced at the expense of villagers' well-being or even lives. According to Harper, the "rhetoric of participatory, sustainable development"—increasingly championed by conservation organizations inside and outside of Madagascar—is hollow (9). It comes back to a question of what is natural? Is there a single 'natural' environment? Are people a part of it? In all cases of conservation, it is important to be cognizant and wary of in whose or what interests are being taken.

In the spirit of Janice Harper, aiming to reverse or lessen the vilification of local populations, more and more recent studies in Madagascar have been examining previously under-emphasized drivers of lemur exploitation; research is beginning to show that rural human populations are not the only, or even the major culprits behind lemur exploitation - specifically the practices of capturing lemurs for the pet trade and hunting lemurs for bushmeat. Kim Reuter (2016) started her study of the bushmeat trade in Madagascar with the expectation that it would be highest in rural areas where food security was low. What she found was the opposite. Urban demand for bushmeat was exorbitant and widespread across the island; it was not just the poorest, uneducated villagers, seeking out an illegal living from the protected land they lived near. On an even more global scale—mentioned earlier in this paper—new perspectives on the illegal capture of lemurs for pets have recently been more thoroughly examined. While it's certain that personal, private pet lemur ownership is a widespread and important problem, many hotels are fueling the lemur trade in Madagascar. These hotels cater to a wide range of customers, both Malagasy and foreign – but it's the wealthy, western ecotourist who most establishments hope to lure in with the amenity of a cute, fluffy, iconic lemur (Reuter and Schaefer 2016; Watson 2016). With the northwestern coast of Madagascar serving as a main tourist and commercial hub on the island, these external pressures bode ill for the lemurs of this area.

All in all, there is no one group on which we can pin the blame for the problems facing lemurs and their habitats. Nor should we idealize or condemn one group of actors over another. The complexity of the goals, values, interests and implications of conservation stand in stark contrast with the simplicity of the situation they battle against. Today—2016, the last year in Schwitzer et al.'s three-year lemur conservation action

plan—the continuing decline in remaining habitat continues to threaten the blue-eyed black lemur and casts an unfavorable light on conservation in Madagascar. There have been conservation measures outlined and implemented in-country for decades, with each passing year heralding calls for more intensive and widespread measures, more funding, more efficacy. Considering this, the complex socio-dependent nature of the conservation problems and how little habitat actually remains to be protected, it seems reasonable to conclude that there is no hope for a reversal or arrestation of habitat loss; the process can only slowed. The survival of this species rests in another, controversial and struggling area: captive breeding.

CAPTIVE POPULATIONS FOR CONSERVATION

Research, Education, Preservation

The World Wildlife Fund (WWF), an NGO working for biodiversity conservation since 1961, defines captive breeding for conservation of endangered species as: "the process of breeding animals outside of their natural environment in restricted conditions in farms, zoos or other closed facilities. The choice of individual animals… (and their) mating partners… are controlled by humans." This organization considers the breeding of endangered species as a 'last resort' strategy due to its difficulty, complex scientific basis, and economic expense. Specifically, under the subheading "*Is captive breeding a useful conservation tool?"* the organization supports its claim that captive breeding is, at best, a supplementary method not only because it can impact the natural fitness of the captive individuals but because it "does not solve underlying problems of habitat destruction, which are often one of the key causes of the species' decline." In spite of this, WWF recognizes the validity of captive breeding programs when they are part of larger, research-based conservation approaches, and aligns its support of such programs to coincide with the IUCN designations of extinction threat. In critical cases like those of most lemur species, the WWF believes that captive breeding programs "need to be established before species are reduced to critically low numbers, and need to be coordinated internationally according to sound biological principles, with a view to the maintaining or re-establishment of viable populations in the wild" (World Wildlife Fund 2007).

Zoos -- the primary holders of captive endangered species -- have long held an exotic fascination for their many visitors who flock to see animals that would otherwise be worlds away, inaccessible or even extinct. There are, however, some—scientists, researchers and other authorities, as well as a large public contingent—who question the validity and ethics of zoo-based conservation. This general aversion stems from a vestigial perception of zoos as "Victorian menageries" and from a time when they were unscientific, poorly-run, exploitative, money-making organizations (Durrell 1976, 17). Gerald Durrell, prompted by a lifelong love of wildlife and biodiversity and, in an effort to change the role of zoos at that time, founded the Jersey Zoo and the Durrell Wildlife Conservation Trust. The novel objectives of this trust were to promote interest in wildlife conservation worldwide, to build up controlled breeding colonies of very threatened species, to organize rescue expeditions of those species, and to amass data/enable research which would help in-situ protection of those animals (Durrell 1976, 23). Many zoos now, following in the footsteps of Durrell and the Jersey Zoo, focus specifically on endangered species conservation. Nonetheless, a contretemps persists, underscored by the very real observations that many animals housed in captivity face a number of problems: stereotypic behavior, increased aggression, changed food searching behavior, changed spatial and temporal behavior as well as the susceptibility to rapid genetic change with or without artificial selection. These problems are all compounded by a lack of reliable guidelines for recognition of animal distress; poor physical or genetic health is often masked by the captive environment (Fa, Funk and O'Connell 2011, 110). Levels of public enmity rest with the ability of institutions to balance how they cater to the demands of their visitors versus the well-being of their animals. One zoo critic went so far as to call all endangered animals held in zoos 'gene-bags,' echoing the argument that, often generations removed from wild ancestors/habitats, captive individuals are not 'real' anymore. Jeffrey Hyson, an assistant professor of history at St. Joseph's University in Philadelphia, argues that zoos need to foreground their ambiguity—acknowledge the line they toe between 'wild' and 'artificial' (Block and Hyson 2005).

But, as stated by the WWF, captive breeding should be considered an essential (if only supplementary) conservation tool. So it follows that zoos housing critically endangered species are equally important institutions. The validity of zoos as conservation, education and research tools is indisputable, especially as

institutions are increasingly better managed by the large number of organizations—regional, national, and global—which have been created to regulate and accredit zoos around the world, striving to alleviate some of the practices and pressures described above which have contributed to the negative reputation zoos have earned. The debate over usefulness aside, the overarching question of zoos and similar organizations, as they pertain to endangered species preservation, shifts to one of purpose: what is the reason for or end goal of having the sub-populations? The answer, which lies in their serving any of three possible roles — as educators or 'ambassadors,' 'model' populations for research, or as possible subjects for reintroduction into the wild —ultimately informs every decision on management made by zoos.

The Blue-eyed Black Lemur in Captivity

There have been 267 blue-eyed black lemurs ever recorded in captivity, a process which began in 1984 (Schwitzer et al. 2006; Peggy Hoppe[6], pers. Com. March 15, 2016). Today, there are 72 animals at 21 different institutions. Most notably, these include the Duke Lemur Center in the United States, Parc Zoologique et Botanique de Mulhouse in France, and Parc Ivoloina in Madagascar, which were the original institutions to receive individuals from the wild (Peggy Hoppe, pers. Com. March 15, 2016). All populations are managed in coordinated breeding programs which culminate in the keeping of a studbook or life-history compilation of captive individuals. In a 2006 discussion and proposal for the conservation of *E. flavifrons*, Schwitzer et al. stipulated that these sub-populations of the blue-eyed black lemur were created to "build up and maintain self-sustaining reserve populations" (144). As such, they were expected to contribute to all three of the distinct captive-population roles, discussed above, for the species' conservation: act as ambassadors as well as 'research substitutes' of the wild populations for the purposes of education, scientific advancement, and providing reservoirs for possible future reintroduction measures. At the time of this publication (2006) little research had been conducted on either in-situ or ex-situ blue-eyed black lemurs. The publication by Schwitzer et al. was primarily a call for more studies to be conducted to test characteristics

[6] Peggy Hoppe is the Zoological Manager of Great Apes at the St. Louis Zoo, Missouri and is the international and regional studbook keeper for *E. flavifrons*.

such as habitat flexibility, edge-tolerance, infant mortality rates and other ecological traits that could influence the survival of the species in the wild. According to the authors, such traits needed "to be studied over the long term, covering a period of at least ten years" (145). Today, ten years later, much more is known about the ecology of *E. flavifrons*, and the role of captive populations remains the same. However, despite our better understanding of the species, the size and genetic viability of these populations—factors necessary for successfully filling the stipulated roles—are suffering.

Captive blue-eyed black lemurs are plagued by many of the common problems facing institutionalized animals—and then some. Until as recently as 2008, this species was particularly prone to obesity in captivity (Schwitzer et al. 2006; Goodchild and Schwitzer 2008). Shifts in diet have lessened the severity of this problem, leaving the biggest remaining threat to captive populations as failure to successfully reproduce. Conception is not the main problem; rather, infant mortality rate is high, with babies often stillborn or dying within a few days of birth. Currently, reasons for this problem are centered around geography and quality of housing, but they remain completely speculative (Peggy Hoppe, pers. Com. March 31, 2016). Low baby survival has led to a captive population struggling in genetic diversity and size. Spread so thin across the globe, the ex-situ groups have little hopes of fulfilling any of the goals imagined for them as educators, supplementary research populations or, least of all, possible sources for reintroduction.

Current Work: MVPs and Collaboration

"Animal populations, if very large, can persist indefinitely and withstand environmental and demographic stochasticity whilst maintaining evolutionary potential" (Fa, Funk and O'Connell 2011, 113). Endangered species, by contrast and definition, are at risk from having very small and fragmented populations. The threat of extinction for a given population increases directly with population fragmentation. Primate communities in highly fragmented landscapes are at high extirpation risk, independent of species extinction (Volampeno et al. 2015). For the blue-eyed black lemur, low total population—estimated at 2,780-6,950 individuals (San Diego Zoo Global Library 2015)—is exacerbated by the extreme habitat fragmentation in Sahamalaza. Within the individual forest fragment of Ankarafa, the population is a

significantly smaller 228 individuals[7] (Volampeno et al. 2010). A population viability analysis (PVA) was conducted in this forest fragment in order to assess viability of the lemurs there. Simulations, which took into account species-specific traits and varying levels of future exploitation, suggest an extinction event within 13 years given a 12 percent increase of habitat destruction (Volampeno et al. 2015). This shocking estimate shows the importance of research and data collection on population statistics and species ecology for conservation actions. The implications of such population viability analyses for fragmentation also validate conservation actions like 'creating corridors between forest fragments,' a measure suggested for Sahamalaza in 2006[8] (Schwitzer et al. 2006).

Population viability is just as important for captive species populations as it is for those in the wild. Given the spatial and financial limitations of zoos in supporting large numbers of individuals, establishing a captive population centers around understanding that species' minimum viable population (MVP). This is how large the population must be to ensure its persistence over a given time, accounting for stochastic (chance) events. Determining this number has been compared to gambling, given the variable rate of past success in establishing effective captive populations. However, it is also noted that, unlike in the wild, captive breeding offers the opportunity to "change the odds in (the breeder's) favor" (Fa, Funk and O'Connell 2011, 112).

The goal for captive breeding was originally put forth as being "the maintenance of 90 percent of the genetic variation in the source (wild) population over a period of 200 years." The current rule of thumb was adapted from this to be a retention of 90 percent gene diversity over a 100 year period (to mitigate the necessary population size by the goal as originally framed) (Fa, Funk and O'Connell 2011, 116). MVP calculations inform most management decisions made by zoos housing endangered species populations. In the past, captive populations faced arguably more fragmentation than many of their wild counterparts; physical and geographic barriers of concrete walls and continental separations rather than corridors of burned forest within a single peninsula. Recently, there has been a push to unify and facilitate collaboration between

[7] Population in 2008
[8] This has yet to be attempted.

institutions housing species like the blue-eyed black lemur in order to counter the debilitating effects of small sub-populations and achieve long-term sustainability of captive populations. MVPs change when world-wide captive populations are viewed as a whole. More and more threatened species are being managed under Global Species Management plans to maintain demographic robustness and genetic purity (World Association of Zoos and Aquariums 2016).

Conservationists are currently working on an 'Accord de Collaboration' between the Species Survival Plan (SSP) in the U.S., the European Endangered Species Plan (EEP) in Europe, and the Madagascar Ministry of Environment, Ecology, Seas, and Forests. This accord is focused on establishing a Global Species Management Plan for the blue-eyed black lemur in the immediate future (Peggy Hoppe, pers. Com. March 31, 2016).

WHAT MORE CAN BE DONE?

A globally managed ex-situ population is a step in the right direction. Nevertheless, as is true with conservation efforts in the wild, these steps have yet to actually solve the physical problems or strengthen the actual captive population of blue-eyed black lemurs. Still, there is hope; successful breeding of critically endangered species for reintroduction has been accomplished in the past. The best comparative example is that of the Golden Lion Tamarin. The Association of Zoos and Aquariums (2014) describes the success story this way:

> In 2003, the Golden Lion Tamarin was downlisted from Critically Endangered to Endangered as a result of nearly thirty years of conservation efforts involving the Golden Lion Tamarin Conservation Program at the Smithsonian National Zoological Park and the Associação Mico-Leao-Dourado in Rio de Janeiro. Conservation efforts included the establishment of a new population through translocation of 47 individuals in six groups, each isolated and evidently otherwise doomed in tiny isolated forests elsewhere, to a new protected area, the União Biological Reserve. Currently, about one-third of the wild population are descendants of the reintroduction program which has contributed significantly not only to the numbers of living in the wild, but also to the protection of 3,100 ha of forests within their range (Association of Zoos and Aquariums 2014).

A national icon within its own unique habitat, the Golden Lion Tamarin is the Brazilian lemur equivalent. There have also been successful cases of captive breeding and reintroduction in other critically endangered lemur species. Since 1997, 13 captive-bred black-and-white ruffed lemurs (*Varecia v. variegata*) were released at Betampona National Park. The reintroductions—deemed a success based on survival, reproduction and integration with the wild individuals—were made possible by the highly prolific captive breeding history of the species (Britt et al. 2004).

Captive populations of *E. flavifrons* have the potential to preserve the entire species. Current populations, however, face reproductive challenges which have so far inhibited them from serving as viable 'reserve populations.' They are struggling in captivity almost as much as their wild counterparts and, even if it were an environmental possibility, they currently could not support reintroduction into the wild. But captivity, unlike the wild, is a man-made environment. Having made the decision to use this captive population as a conservation mechanism, there should be more that is within our power to control and manage effectively to breed larger captive populations of the blue-eyed black lemur. Some possible suggestions to ameliorate the breeding of this species in captivity and to combat the issues it faces currently include: larger co-housed social groups, a more intense regulation of environmental conditions and scientific facilitation of individual breeding.

Social Grouping

With few exceptions, primates are highly social animals. Lemurs live in social groups of varying sizes with those of the blue-eyed black lemur ranging from 4 to 11 individuals. Being a female dominant species, there are rarely more than three adult females to a group (San Diego Zoo Global Library 2015). At the Como Zoo and Conservatory in Saint Paul, one female, Thurman, is housed with one male, Eugene. These two were brought together after a number of failed attempts to induce Thurman to conceive with other males. Eugene is another in a line of introduced and subsequently rejected suitors. As of 2015, Eugene had yet to distinguish himself from that crowd (pers. observation). This transitory breeding pair situation mirrors the grouping of many captive individuals. Few institutions house more than a handful of lemurs together, partly

due to the complexity of lemur social groups and in part to the psychological, physical and economic burden associated with forming successful ones. While the advances in worldwide institutional collaboration (following the GSMP described above) have greatly facilitated the mobility of breeding individuals between locations, I believe that the establishment of larger, long-term social groups could greatly improve the breeding of this species by creating a more naturalistic environment and giving females wider access to males.

Environmental Regulation

In a similar vein, zoos should continue to aim at making the living conditions of the lemurs as close to what they would be in-situ as possible. Such considerations could have direct benefits on breeding success. For example, light cycles have been identified as important controllers of breeding in the majority of vertebrate species. Yet captive lemurs (under natural light) experience breeding seasons differing by up to half a year from those they would experience in Madagascar (Van Horn 1975). Careful consideration of ecological factors—especially those associated with reproduction—should be taken when designing a captive facility for lemurs if breeding is to be successful.

Scientific Support

Finally, there are technologies in existence today which have the potential to greatly ameliorate the breeding of captive species like the blue-eyed black lemur. These include artificial insemination, embryo transfer, in-vitro fertilization, and genome resource banking, among others. Controlling for more natural ecological factors like photoperiod regulation, social-group size and diet may well boost the physical and psychological robustness of captive individuals. To augment that, these methods, in theory, conserve viable germplasm and embryos, allowing zoo managers to hedge against many other captivity issues like genetic drift, inbreeding, genetic adaptation and population crashes. In reality, however, they are rarely used and extremely controversial for a number of reasons: many methods remain largely untested and, in many instances, are not performed due to inadequate species knowledge. There is also a widespread unease

surrounding the reliance on technical solutions to solve problems. Methods such as these are argued to be palliative, "targeting the symptoms but not the causes of biodiversity loss" (Fa, Funk and O'Connell 2011, 139). This argument should sound familiar as it echoes that put forth against a reliance on captive breeding itself as a conservation tool. Yet as with any illness, symptoms should be addressed with alacrity.

Summary

A push for more invasive methods to mitigate the struggles faced by captive populations of *E. flavifrons* centers around a single point, epitomized by the debate over use of reproductive technologies in captive breeding: humans—accepting that a larger captive population is the last hope and should be the primary goal for the conservation of the blue-eyed black lemur—should have little reservation when it comes to what measures they are willing to take to create such a viable captive population. Captivity, in and of itself, is a technological solution. Furthermore, we come full circle to the question, what is 'natural?' Are reproductive technologies 'unnatural?' Are animals in zoos 'unnatural?' Is the current level of human impact on the environment—the same which drives us to develop these conservation strategies— 'unnatural?' The term natural is arbitrary. It should not be considered a relevant argument against any conservation strategy that might save a species from extinction. Future research needs to identify the reasons behind problems such as the high rates of infant mortality that the blue-eyed black lemur is experiencing in captivity. If it can be confirmed that—as speculated—reproductive success is linked to how closely captive environmental conditions mirror those the lemurs would be experiencing in the wild, we could immediately begin to make the changes necessary to grow the captive population (changing group housing methods and controlling for variables like light cycles, temperature, etc.). If the reasons remained a mystery, we could conclude that a different yet equally immediate measure would be needed – namely, the use of reproductive technologies. Such technologies are by no means a long-term solution to captive breeding problems. Note, however, the recurrent use of the word 'immediate' in the former sentences; both in-situ and ex-situ conservation measures have so far been characterized by the proposal of long-term, hypothetical solutions. With such little habitat left and such dwindling population numbers, there is no time for more 3-year action plans. The

maintenance of the current blue-eyed black lemur meta-population exhibits a complacency surrounding growing the population for reintroduction and an irrational unease towards what are thought of as ersatz solutions to major problems. Clearly, conservation problems within Madagascar are complex and hard to address directly. In captivity, the opposite is true; immediate solutions are available to us and could buy this species much-needed time and security.

WHY CONSERVE THE BLUE-EYED BLACK LEMUR?

Not Your Average Lemur

It's important to note the economic burden and wealth of resource investment required for successful implementation and upkeep of captive populations. Zoos cannot possible house viable populations of all endangered animals in the world. Why should so much money, time, research, space, and energy be allocated to the blue-eyed black lemur—simply one out of the many living and equally threatened lemur/mammal/vertebrate/animal species in the world? The morphological and ecological characteristics unique to *Eulemur flavifrons* both make it an ideal representative of lemurs as a whole but also set it apart as a species with the potential to be saved. The genus name '*Euleumur'* means 'true lemur' and encompasses twelve species found in almost all forested habitats across Madagascar[9]. Due to this large geographic distribution, they exhibit a wide range of morphological adaptations. They are also thought to be the most recently diverged genus of lemur, making their variability an even more impressive feat of adaptive radiation (Donati and Johnson 2016). Within this genus, the blue-eyed black lemur is further noted for its adaptability. A study by Schwitzer et al. (2007) compared habitat utilization of *E. flavifrons* between primary and secondary forest within Ankarafa. While the species was clearly better suited to the primary habitats (exhibiting smaller home range sizes, having access to a greater number of large trees used for eating and

[9] This stands in contrast with the genus *Lemur* with 1 species (*L. catta*) and a tiny geographic range in southern Madagascar, or the genus *Varecia* with 2 species (*Varecia variegata, Varecia rubra*), only found in eastern tropical rainforests.

resting and being more shielded from predators), a high level of ecological flexibility and edge-tolerance was evident. This is further supported by the more recently observed hybridization between *E. flavifrons* and *E. macaco*, described above; this genus and, more specifically this species, *flavifrons*, is highly adaptable and constantly finding new ways to survive. This plasticity bodes well for its conservation. It would be a daunting task to maintain viable captive populations of all the lemur species which are critically threatened (over 100). The blue-eyed black lemur shows the capacity to not only survive in, but adapt to constantly changing and sub-optimal conditions. Environmentally, it's unlikely that the pristine, primary forests in which the blue-eyed black lemur evolved will be around much longer or will ever be reestablished. But with a captive population large enough to entertain the idea of reintroduction, the possibility for such an action remains a much more tangible reality than it would for many other species of lemur.

A Problem of Awareness

No matter what one's opinion on zoos as institutions or animals being held in captivity is, both hold an undeniable value for conservation efforts. What it comes down to is education; whether discussing in-situ conservation of wild lemurs, ex-situ lemurs in captivity, or the conservation of endangered species/habitats in general, the story remains a narrative of widespread pressures and problems (man-made) which, hence, require a vast and communal effort to change. The Malagasy forests are not being destroyed solely by the impoverished local people, exploiting their endemic resources out of ignorance and for short-term survival. While certainly a contributing factor, it is more a problem exacerbated by the pressures and demands of our western societies; we are the populations which consume the rosewood and demand the cash crops like vanilla. On an even broader scale, earth-wide global warming is one of the ultimate drivers of habitat loss and certainly cannot be pinned on a single community/country/population. Humans as a collective are causing these problems, and so it will take an equally universal effort—from multiple levels and perspectives—to slow, stop or reverse them. However, people cannot contribute to a solution if they are unaware of a problem. This is where a larger captive population of the blue-eyed black lemur comes into play.

At the Como Zoo and Conservatory in Saint Paul, Minnesota, the first exhibit visitors see upon entering the primate building is the enclosure which houses two blue-eyed black lemurs: Thurman and Eugene. Working there as an intern, I spent many hours right inside the building door, conducting an observational study of these two individuals. Those long observation periods also allowed me to watch the other primates surrounding me: people. As all manner of visitors flooded into the zoo daily, reactions to seeing the lemurs—exclamations of how cute they were—were undercut by confusion and curiosity: "Awww they're so fluffy." "Why is one red and one black?" "Mom, look! They're hugging each other!." The majority of initial reactions, though, went something like this; "what is that?!" "I think it's a cat… no, maybe a skunk!" …

I found a similar dearth in knowledge of basic geography and biology when I began to tell people I'd be or had been studying abroad in Madagascar, conducting research on lemurs. From family and friends, classmates, colleagues, and strangers alike, I most often received a blank stare and vague signs of interest. I found I was lucky if the person I was talking to had ever heard of a lemur. If I told them, subsequently, that it was a primate, I was equally likely to be misunderstood. Often, I simplified, saying, "it's like a monkey" which satisfied the majority of people's curiosity. Awareness of the island of Madagascar, I found, was even more lacking. If people knew it was a part of Africa, they rarely knew where, (Western? Mainland? Near Australia?), and their knowledge/association often stemmed solely from the animated movie '*Madagascar,'* in which penguins roam Malagasy shores.

If the majority of the world's population has no idea where or what Madagascar is, how can they be sympathetic to the plight of a dwindling, mysterious, 'skunk-like' animal they've never heard of? One of the major repercussions of Madagascar's political crisis was a decrease in outside funding for conservation measures. That funding is hugely supplemented by public donation. Every organization's website has a *'donate'* or *'support us*' button where visitors of the page are encouraged to offer varying levels of financial support. As a subscriber to the corporation *Amazon.com*, consumers are prompted to choose a 'charity' to support with a percentage of every purchase automatically donated to that organization; World Wildlife Fund is one of those charity options. Funding for outreach events, research grants, governmental programs and

many other conservation efforts are all supplemented by public donation. Without such funding, progress could not be made. Today, everyone recognizes the iconic panda that serves as the logo for WWF; most people have been solicited in some way or another to donate to a tiger conservation fund. Yet no one has heard of a lemur. Are they rodents? Are they weasels? Do they live in Antarctica with the penguins? Or do penguins live in the tropics? Who knows? Certainly not your average American citizen. However, now all the people who have visited Como Zoo in Saint Paul know, many of whom would still be oblivious to the existence of lemurs and many of the other animal species housed there were it not for their decision to visit one sunny day.

It is often pointed out that zoos do not have the resources, economic or spatial, to house 'viable' populations of all species endangered in the wild. Conservation priority, at present, is often given to iconic megafauna, taxa such as elephants, polar bears, pandas and tigers which draw floods of curious visitors and (are believed to) increase profit[10]. But like pandas and tigers, lemurs are iconic, keystone species within their environments. And given their close relation to humans, they should be of even higher interest to people than some of their other red-list compatriots. However, unlike the highlighted zoo taxa and compared to many groups of equal or lesser conservation status, public awareness of lemurs is shockingly low outside of Madagascar. Larger populations of *E. flavifrons* held in captivity would increase awareness and outside investment in the species, its native habitat and its conservation.

Captive populations of *E. flavifrons* exist within Madagascar too. However, as in America, I found that the average Malagasy person, outside of the direct Sahamalaza area, was unlikely to have heard of or know anything about *'Le Lémur aux yeux turquoise.'* The more access Malagasy people had to this and other endangered species outside of their immediate home ranges, the more widespread the awareness and education for their conservation would be. Famed naturalist E. O Wilson, when interviewed about his radical proposition to "set aside half the world for conservation," suggested that this extreme measure could indeed be feasible in light of the observations that; "when people have property in a national natural landmark, they

[10] Arguably, studies have shown that large-bodied taxa may not be as profitable for zoos as are smaller-species exhibits which require fewer resources and seem to attract an equal if not higher number of visitors (this especially true for social animals like lemurs) (Fa, Funk and O'Connell 2011, 79).

tend to have pride in it and make sensible use of it" (Worrall 2016). Sahamalaza is one of the many national parks upon which this observation is based. Sectioning it off has so far had little effect on its preservation. But if national pride can help conserve half the world, it should certainly be able to save habitats on an isolated African island. That pride, however, can only be established from the ground up. For the blue-eyed black lemur, that starts with educating the local populations of Sahamalaza, followed by the Malagasy people, and through to the entire world. Education promotes awareness and understanding of value which, in turn, drives every aspect of conservation, from funding to methodology. And education rests on the accessibility and viability of captive populations.

For the Good of Us All

The intrinsic value of biodiversity is painfully obvious to many. Others recognize the importance of keystone species like lemurs for their diverse ecological roles and the benefits they provide to people; species richness has been shown to have a direct correlation to community competence. The greater biodiversity within an area, the less disease and other pathological problems occur for all members of that system (Johnson et al. 2013). More specific to Madagascar, lemurs are the main, important seed dispersers in the forests that they inhabit. When they go extinct, entire ecosystems fall apart. The trees and plants which provide medicine, fruit, shelter and other amenities to human populations, cannot survive (Than 2016). But still there are those who—though they can appreciate the cute, fluffy, blue-eyed animal staring at them through enclosure glass—see little point in putting useful money and technology towards 'saving' it, especially if it's so close to extinction. To those people, I I would point out two very specific concepts which have been gracing popular media with increasing regularity. A recent Washington Post article (Landers 2016) summarized the two movements—de-extinction and re-wilding—through a discussion of the Auroch: a huge, cattle-like beast that went extinct around the Bronze Age. De-extinction is the idea of using varying genetic technologies to re-create living populations of animals which are extinct today. These include species like the wooly mammoth, the passenger pigeon, and the Tasmanian tiger, all of which were outcompeted by human activity. Given the aforementioned observation—that ecosystems fall apart when they lose important

species— the habitats which supported creatures like the mammoth, are as extinct as their once-iconic fauna. Enter the second movement: rewilding. This is similar to de-extinction in that it proposes to set aside large tracts of land, restoring them as closely as possible to their "pre-human state" (Landers 2016, 2). The two movements go hand-in-hand. Noting: one, that there are now many organizations established to research, fund and implement projects in these two fields,[11] and two, the fact that they are showing up in many scientific and popular news sources[12] —it is clear that these ideas appeal to many people who entertain them as feasible and necessary 'conservation' actions.

Conservation centers around the success or failure of the balancing act humans play with their natural environment. Man has already pushed many species and habitats to extinction. Public attention and support of the re-wilding and de-extinction movements demonstrate a widespread sentiment of loss and regret, as well as intense interest in species driven to extinction at the hand of mankind. But these projects—which call for technologies similar to those suggested above for better captive reproduction—are expensive and resource intensive. They take away from the desperately needed funding and attention to animals which do not need to have entire habitats recreated for them – they simply need to have their current ones better protected. These movements also undermine current conservation work by promoting a complacency surrounding the extinction of endangered animals. Why take such great pains to save species if we can 'simply' bring them back to life? Public sympathy and support could be better directed towards saving animals like the blue-eyed black lemur and its unique Malagasy ecosystem.

CONCLUSION

Above, I have argued why more emphasis needs to be placed on the curation and growth of captive populations of *E. flavifrons* to ensure the survival of the species. Many view these subpopulations, as well

[11] These include: the *Taurus Program*, *Rewilding Europe*, and *Revive and Restore* (a part of the *Long Now Foundation*).
[12] Simply Google search 'de-extinction' – major organizations covering this topic include National Geographic, The Smithsonian, The BBC, and CNN among others.

as the institutions housing them, very critically—as 'last resort' conservation measures. At what point, then, does a 'last resort' become the best remaining option? For the blue-eyed black lemur, that point has arrived. Faced with a bleak future in its natural habitat, this species is a case study for many of Madagascar's endemic primates. The in-situ conservation regimes for their conservation—grounded in strong and, in other cases, successful theories and actions—have elicited little in the way of tangible results. The Sahamalaza peninsula—already an established national park and UNESCO biosphere reserve—continues, in spite of intense conservation efforts, to face major environmental pressures: severe habitat fragmentation and lemur population decline from illegal logging, agricultural practices and the bushmeat/pet trade within the boundaries of the protected area. As I have described, there are clearly outlined measures necessary to further the in-situ conservation of the blue-eyed black lemur and other critically endangered species that either expand upon or add to those already in place. This paper is not a call to abandon those efforts and goals. The preservation of original habitats and ecosystems is the ideal which drives all subsequent actions, in-situ and out. Instead, my argument is based upon the observation that too many multi-year action plans have been proposed; of these plans, few have achieved their stated goals or any measurable success in the way of forest or lemur preservation. This paper is a call to action. In this age of the Anthropocene, barring some cataclysmic extinction of the entire human race, we can, at best, only slow the further deterioration of the *flavifrons'* natural habitat—a habitat which, at present, is barely able to sustain viable populations. Hence, we must find a way to make the captive breeding of this species more successful and significantly increase its numbers outside of Madagascar. This would in turn, help supplement conservation in the wild.

I recently returned from presenting my research on *E. flavifrons* in Madagascar at the 85th annual meeting of the American Association of Physical Anthropologists in Atlanta, Georgia. One lemur primatologist, upon hearing my project summary, responded conversationally by saying "that's cool that you were one of the last people to see blue-eyed black lemurs in the wild." He said it calmly, in a matter-of-fact kind of way, genuinely impressed and jealous of this privilege that I hadn't realized might have been mine. I nodded and agreed with him that I was very lucky. Internally, however, it was startling to hear

someone confirm the probability of their imminent extinction - most people prefer to maintain hope that something will change.

This paper is about lemurs. It is also about the island of Madagascar. It's about the theoretical and physical frameworks of conservation and it's about the past, present and the future. Yet in the end, everything circles back to people. The case of the blue-eyed black lemur, like that of all species threatened by extinction at the hand of anthropogenic pressures, is ultimately a story about people: people causing problems, people creating solutions. Reserves, national parks, and ecotourism are all human-based efforts to assuage human-induced pressures. Zoos are also one of these 'solutions'. It is sad that limitations require us to pick and choose which species to conserve and which to leave to the unfeeling hand of natural selection. The failure of in-situ conservation is an illustration of the extreme lack of power we wield over the massive effects we are inflicting on wild habitats. However, the fact that we *get* to pick species to conserve is a demonstration of the opposite: the extreme power and control we exert in ex-situ environments. As we are slowly realizing the great value of the biodiversity which exists around us, conservation and preservation are becoming more of a priority. For species like the blue-eyed black lemur, it may be too late. As a 'true lemur' and the flagship species of the Sahamalaza peninsula, it represents all the lemurs of Madagascar: Iconic symbols of national identity for the Malagasy, oldest primate relatives of the human race. As such, we should do all within our (considerable) power to keep them around far into the future.

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Executive Summary

BLUE EYES ON RED LISTS: *Conservation and the Future of the Blue-eyed Black Lemur*

Katherine Meier - Macalester College . Department of Anthropology - Senior Capstone - 4/29/16

The family *Lemuridae* represents a large and important group within the order *Primate*. As members of this order ourselves, we view lemurs as the most primitive of the primates, our oldest living relatives. Today, lemurs—only found on the island of Madagascar—are considered the most threatened mammal group on Earth. Almost every one of the over 100 species

recognized, is suffering from rapidly disappearing habitat and plummeting population numbers. These threats stem from a wide range of anthropogenic pressures, most notably practices like slash-and-burn agriculture and poaching. The blue-eyed black lemur is one of these species. Restricted to the Sahamalaza peninsula in northwestern Madagascar, this species is special: Arboreal, frugivorous, sexually dimorphic, female-dominant, and critically endangered. This species, like many lemurs, is menaced by a wide range of pressures, mostly anthropogenic, including slash-and-burn agriculture and poaching. These problems are fueled by a complex web of actors with conflicting interests. Sahamalaza was partitioned as a protected area since 2001 and there are multiple conservation organizations active in the area. So far, however, their efforts have yielded little measurable success. Locals continue to exploit the forest, while outsiders fuel demand for pet lemurs other exoticized, endemic resources. All these problems are compounded by the ongoing political turmoil which has plagued Madagascar since 2009. With so little habitat currently remaining to be saved, it's unlikely that anything can stop the deterioration of Sahamalaza's ecosystems.

For the blue-eyed black lemur, captive populations—which typically serve as buffers against extinction—are not currently large enough to be viable for reintroduction into the wild, were it an ecological possibility. There are 72 lemurs currently housed at 21 different institutions across Madagascar, Europe and the U.S. The meta-population's growth is inhibited by problems like high rates of infant mortality, the reasons for which are unknown. Without a viable captive population, this species imminent extinction is solidified. Unlike in the wild, captivity is a human controlled environment; managers of zoo-held populations have the power to control for variables like social group size, light cycles, temperature, and diet. Today, reproductive technologies exist that would allow for an immediate solution to the low reproductive success of these lemurs. Given the time-frame predicted for this species, it is imperative that we, humans, act now and do all that is within our power to keep the blue-eyed black lemur around for generations to come.

Captive housing and breeding is an extreme financial and special burden. Many zoos only house the most iconic and endangered mega-fauna like tigers, polar bears and pandas. The blue-eyed black lemur, however, is equally deserving of space and resources allocated to its as any species. Among lemurs, this species is very flexible in varying environments. It shows the capacity to not only survive in, but adapt to constantly changing and sub-optimal conditions. On a larger scale, it is the poster-child species for conservation efforts in Sahamalaza, its natural habitat. This is due to its winning visage – the blue-eyed black lemur is the only primate other than humans to have blue eyes—which endears it to anyone fortunate enough to see it.

My paper is a call to action – a call to immediate action. The blue-eyed black lemur, if current rates of exploitation persist (or grow), cannot last long in the wild. It follows that zoos and captive breeding of viable sub-populations are the best hope for the future survival of this species. Primates, like this lemurs, are our closest living relatives. The human race shows an ongoing fascination with them. More recently, the importance of biodiversity and its conservation is being recognized by everyone. These interests make the blue-eyed black lemur a prime candidate for conservation efforts. Yet, even though we have the power and technology to solve the captive reproduction issues in this species, people continue to shy away from invasive, 'artificial' conservation strategies – showing alarming complacency in the efficacy of conservation actions. Ultimately, man is a part of the natural environment. There is no solution too 'unnatural' if it saves a species from extinction. We have power and control in captive environments that contrasts that we wield in natural habitats. We can and should use it.